Genus *Pratylenchus* Filipjev: multientry and monoentry keys and diagnostic relationships (Nematoda: Tylenchida: Pratylenchidae)

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Ryss, A.Y. 2002. Genus *Pratylenchus* Filipjev: multientry and monoentry keys and diagnostic relationships (Nematoda: Tylenchida: Pratylenchidae). *Zoosystematica Rossica*, **10**(2), 2001: 241-255.

Tabular (multientry) key to *Pratylenchus* is presented, and functioning of the computerized multientry image-operating key developed on the basis of the stepwise computer diagnostic system BIKEY-PICKEY is described. Monoentry key to *Pratylenchus* is given, and diagnostic relationships are analysed with the routine taxonomic methods as well as with the use of BIKEY diagnostic system and by the cluster tree analysis using STATISTICA program package. The synonymy *Pratylenchus scribneri* Steiner in Sherbakoff & Stanley, 1943 = *P. jordanensis* Hashim, 1983, **syn. n.** is established. Conclusion on the transition from amphimixis to parthenogenesis as one of the leading evolutionary factors for *Pratylenchus* is drawn.

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Identification of nematode species is difficult because of relative poverty and significant intraspecific variability of diagnostic characters. The genus *Pratylenchus* Filipjev is an example of a group with large number of species (49 valid species; more than 100 original descriptions) and complicated diagnostics. The genus has a worldwide distribution and economic importance as its species are the dangerous parasites of agricultural crops. *Pratylenchus coffeae* is a species of the world quarantine importance. Economically important species are also the following: *P. loosi,* the pest of tea plants (*Thea sinensis)*; *P. goodeyi,* parasite of bananas (*Musa* spp.); *P. penetrans,* pest of potatoes and cereals; *P. neglectus, P. fallax* and *P. scribneri,* pests of cereals. Taking in account its broad distribution, the significant host range and large species number, the genus can be considered as a taxon being at the stage of biological progress (Ryss, 1988).

Here the tabular (multientry) key is presented, and functioning of the computerized multientry image-operating key is described; the latter is developed on the basis of the stepwise computer diagnostic system BIKEY-PICKEY (Lobanov & Dianov, 1994, 1995; Lobanov et al., 1996; Dianov & Lobanov, 1997). In addition, the monoentry key to the genus is given, and diagnostic relationships are analysed with the routine taxonomic methods as well as with the use of BIKEY diagnostic system, and by the cluster tree analysis using STATISTICA program package (STATISTICA, 1995).

Material and the basic information sources

The collections of the following institutions were used in research: Zoological Institute, Russian Academy of Sciences; Institute for Nematology and Vertebrates, Münster, Germany (German National Collection of Nematodes); Agricultural University, Wageningen, The Netherlands; Museum of Natural History, Paris, France; Institute of Parasitology, Moscow, Russia.

Material for investigation was loaned by Prof. M. McClure (University of Arizona, USA), Dr. L.M. Shagalina (Institute of Zoology, Ashkhabad, Turkmenistan), Dr. T.S. Ivanova (E.N. Pavlovsky Institute of Zoology and Parasitology, Academy of Sciences, Dushanbe, Tadjikistan), Prof. O.Z. Metlitzky (Institute of Horticulture, Russian Academy of Agricultural Sciences, Moscow, Russia), Dr. A.S. Eroshenko (Institute of Biology and Soil Science, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, Russia).

The database of characters of the *Pratylenchus* species in MS Excel and MS Access (Ryss, 1998) as well as the numerous literature sources cited in the list of the *Pratylenchus* species below, have been used for this review.

List of species of the genus *Pratylenchus* (including synonymy)

Type species: *Tylenchus pratensis* De Man, 1880, by original designation.

Pratylenchus alleni Ferris, 1961. – Ferris, 1961: 109-111; Ryss, 1988: 118-120.

Pratylenchus andinus Lordello, Zamith & Boock, 1961. – Lordello et al., 1961: 213-215, figs L, M; Corbett, 1983: 391-394, figs 1, 5 (a, b), tables 1, 2 (redescription with the neotype designation).

Pratylenchus australis Valenzuela & Raski, 1985. – Valenzuela & Raski, 1985: 330-333, figs 1 (a-k), 2 (a-f).

Pratylenchus barkati Das & Sultana, 1979. – Das & Sultana, 1979: 9-10, pl. 3, figs 1-4.

Pratylenchus bolivianus Corbett, 1983. – Corbett, 1983: 394-396, figs 2, 5 (e, d).

Pratylenchus brachyurus (Godfrey, 1929). – Godfrey, 1929: 617-622, figs 6-8 (*Tylenchus*); Filipjev, 1934: 149-150, fig. 126 [*Tylenchus* (*Chitinotylenchus*)]; Goodey, 1951: 114; Sher & Allen, 1953: 450, pl. 65 (d, e, i) (redescription of topotypes). – *leiocephalus* Steiner, 1949: 37, fig. 27. – *steineri* Lordello et al., 1954: 141-149. – *pratensis* (non De Man, 1880): Goodey, 1932: 115 (*Anguillulina*); Schneider, 1939: 227 [(*Anguillulina* (*Pratylenchus*)]; Filipjev & Shuurmans Stekhoven, 1941: 242.

Pratylenchus coffeae (Zimmerman, 1898). – Zimmerman, 1898: 16-34, figs 3-10 (*Tylenchus*); Goodey, 1951: 114; Sher & Allen, 1953: 448, pl. 65 (b, g) (redescription with the neotype designation). – *musicola* Cobb, 1919: 179-182, fig. 1 (*Tylenchus*); Filipjev, 1936b: 81. – *mahogani* Cobb, 1920: 188-191, figs 1-3 (*Tylenchus*); Filipjev, 1936b: 81; Goodey, 1937: 133-136, figs 1-6 (*Anguillulina*). – sp.: Schneider, 1938: 88-89 [*Tylenchus* (*Chitinotylenchus*)]. – *pratensis* (non De Man, 1880): Filipjev & Shuurmans Stekhoven, 1941: 242.

Pratylenchus convallariae Seinhorst, 1959. – Seinhorst, 1959: 83-85, fig. 1 (a, b).

Pratylenchus crassi Das & Sultana, 1979. – Das & Sultana, 1979: 12-14, pl. 5, figs 1-5.

Pratylenchus crenatus Loof, 1960. – Loof, 1960: 46-48. – *clavicaudatus* Baranovskaya & Haque, 1968: 759-761, fig. 1. – *pratensis* (non De Man, 1880): Goffart, 1929: 100-106, Abb. 1-4, tables 1, 2 (*Anguillulina*; part.); Thorne, 1949: 51-53, fig. 3.

Pratylenchus dasi Fortuner, 1985. – Fortuner, 1985: 81. – *capitatus* Das & Sultana, 1979: 7-9, pl. 2, figs 1-5 [nom. praeocc., non *Pratylenchus capitatus* Ivanova, 1968 = *P. neglectus* (Rensch, 1924)]. – *hyderabadensis* Singh & Gill, 1986: 139.

Pratylenchus delattrei Luc, 1958. – Luc, 1958: 13-14, pl. 2.

Pratylenchus ekrami Bajaj & Bhatti, 1984. – Bajaj & Bhatti, 1984: 366, fig. 3 (a-i), table 1.

Pratylenchus emarginatus Eroshenko, 1978. – Eroshenko, 1978: 33, fig. 1.

Pratylenchus estoniensis Ryss, 1982. – Ryss, 1982: 22-24, fig. 1.

Pratylenchus exilis Das & Sultana, 1979. – Das & Sultana, 1979: 10-12, pl. 4, figs 1-6.

Pratylenchus fallax Seinhorst, 1968. – Seinhorst, 1968: 505-507, fig. 3 (a-f). – sp.: Pitcher et al., 1966: 379-396.

Pratylenchus flakkensis Seinhorst, 1968. – Seinhorst, 1968: 507-508, fig. 4 (a-e).

Pratylenchus gibbicaudatus Minagawa, 1982. – Minagawa, 1982: 418-420, fig. 1.

Pratylenchus goodeyi Sher & Allen, 1953. – Sher & Allen, 1953: 455-456, pl. 65, fig. 1 (p, q). – *musicola* (non Cobb, 1919): Goodey, 1928: 194-197, figs 1-5 (*Tylenchus*).

Pratylenchus hexincisus Taylor & Jenkins, 1957. – Taylor & Jenkins, 1957: 160-163, fig. 1.

Pratylenchus impar Khan & Singh, 1975. – Khan & Singh, 1975: 204-206, fig. 3.

Pratylenchus japonicus Ryss, 1988. – Ryss, 1988: 165-166, fig. 48 (*macrostylus* subsp. *japonicus*); Mizukubo, Orui & Minagawa, 1997: 203-214 (pro species). – sp.: Gotoh & Ohshima, 1963: 195, 199, figs 2 (h), 3 (i-j); Gotoh, 1974: 142 (*Hoplotylus*). – *macrostylus* (non Wu, 1971): Minagawa, 1982: 420-423, fig. 2.

Pratylenchus kasari Ryss, 1982. – Ryss, 1982: 24-26, fig. 2. – *pratensobrinus* Bernard, 1984: 198-200, figs 13-17, table 3. – *morettoi* Luc, Baldwin & Bell, 1986: 119-123, figs 1, 2.

Pratylenchus loosi Loof, 1960. – Loof, 1960: 58-59, fig. 9 (f-i). – *pratensis* (non De Man, 1880): Gadd & Loos, 1941: 39-51 (*Anguillulina*). – *coffeae* (non Zimmerman, 1898): Loos, 1953: 34-38.

Pratylenchus macrostylus Wu, 1971. – Wu, 1971: 487-489, figs 1-8.

Pratylenchus microstylus Bajaj & Bhatti, 1984. – Bajaj & Bhatti, 1984: 361, fig. 1 (a-i).

Pratylenchus mulchandi Nandacumar & Khera, 1970. – Nandacumar & Khera, 1970: 359-363, figs a-j. – *manohari* Quraishi, 1982: 208-210, pl. 3, fig. 4.

Pratylenchus neglectus (Rensch, 1924) – Rensch, 1924: 277-279, fig. (*Aphelenchus*); Chitwood & Oteifa, 1952: 162; Loof, 1960: 55, figs 3, 4 (e-f), 5-8, tables 1-2 (redescription with the neotype designation). – *minyus* Sher & Allen, 1953: 449, pl. 65 (j, k, n, o). – *capitatus* Ivanova, 1968: 45-46, fig. 5. – *neocapitatus* Khan & Singh, 1975: 206-208, fig. 4. – *pratensis* (non De Man, 1880): Filipjev & Shuurmans Stekhoven, 1941: 242.

Pratylenchus nizamabadensis Maharaju & Das, 1981. – Maharaju & Das, 1981: 24-25, fig.

Pratylenchus penetrans (Cobb, 1917). – Cobb, 1917: 32 (*Tylenchus*; part.); Chitwood & Oteifa, 1952: 162. – *gulosus* Kühn, 1890: 93-94, fig. (*Tylenchus*); Sher & Allen, 1953: 453, pl. 67 (a-g) (redescription with the neotype designation). – *subpenetrans* Taylor & Jenkins, 1957: 163-166, fig. 2. – *singhi* Das & Sultana, 1979: 5-7, figs 1-4, pl. 1. – *kralli* Ryss, 1982: 26-28, fig. 3. – *ventroprojectus* Bernard, 1984: 200-201, figs 18-22, table 4. – *pratensis* (non De Man, 1880): Steiner, 1927: 961-967, fig. 2 (a, b, d) (*Tylenchus*); Goodey, 1932: 115-116, figs 43-47 (*Anguillulina*); Filipjev & Shuurmans Stekhoven, 1941: 242.

Pratylenchus pinguicaudatus Corbett, 1969. – Corbett, 1969: 550-552, fig. 1.

Pratylenchus pratensis (De Man, 1880). – De Man, 1880: 71 (*Tylenchus*); Filipjev, 1936b: 81; Loof, 1960: 41-43, figs 2,10 (redescription with the neotype designation). – *helophilus* Seinhorst, 1959: 85-86, fig. 1 (c, d, e). – *irregularis* Loof, 1960: 44-46, fig. 11. – sp.: Paetzold, 1958: 30-31, Abb. 7 (a-d).

Pratylenchus pseudocoffeae Mizukubo, 1992. – Mizukubo, 1992a: 438-443, table 1, figs 1-3.

Pratylenchus pseudopratensis Seinhorst, 1968. – Seinhorst, 1968: 508-509, fig. 4 (h, i, j, l, m). – *mediterraneus* Corbett, 1983: 339-402, figs 4-5 (g, h). – *thornei* (non Sher & Allen, 1953): Orion et al., 1979: 3-9.

Pratylenchus ranjani Khan & Singh, 1975. – Khan & Singh, 1975: 199-202, fig. 1.

Pratylenchus scribneri Steiner in Sherbakoff & Stanley, 1943. – Sherbakoff & Stanley, 1943: 69; Sher & Allen, 1953: 450, pl. 65 (m, t) (redescription, not on the type material but on the material from Florida, USA, *Hipperastrum* sp. roots according to the host re-identification in Loof, 1960; in Sher & Allen, 1953, the host was misidentified as *Amaryllus* sp.). – *agilis* Thorne & Malek, 1968: 65-66, fig. 29 (a, b). – *jordanensis* Hashim, 1983: 188, fig. 1 (a-h), **syn. n.** (see discussion below). – *penetrans* (female fig., in the original description of *P. penetrans* Cobb, 1917): Cobb, 1917: fig. 1 (*Tylenchus*). – *pratensis* (non De Man, 1980): Filipjev & Shuurmans Stekhoven, 1941: 242 (part.).

Pratylenchus sefaensis Fortuner, 1973. – Fortuner, 1973: 25-27, fig. 1.

Pratylenchus sensillatus Anderson & Townshend, 1985. – Anderson & Townshend, 1985: 2378-2382, figs 1-13.

Pratylenchus similis Khan & Singh, 1975. – Khan & Singh, 1975: 202-204, fig. 2.

Pratylenchus subranjani Mizukubo, Toida, Keereewan & Yoshida, 1990. – Mizukubo et al., 1990: 312-317, tables 1, 2, figs 1-3.

Pratylenchus sudanensis Loof & Yassin, 1971. – Loof & Yassin, 1971: 537-539, fig. 1.

Pratylenchus teres Khan & Singh, 1975. – Khan & Singh, 1975: 209-210, fig. 5.

Pratylenchus thornei Sher & Allen, 1953. – Sher & Allen, 1953: 454-455, pl. 65 (c, h). – *cruciferus* Bajaj & Bhatti, 1984: 361-365, fig. 2, table 1.

Pratylenchus unzenensis Mizukubo, 1992. – Mizukubo, 1992b: 534-538, table 1, figs 1-3.

Pratylenchus vulnus Allen & Jensen, 1951. – Allen & Jensen, 1951: 48-50, fig. 1; Sher & Allen, 1953: 451, pl. 66 (a-i) (redescription of the type material). – *typicus* Rashid & Khan, 1976: 68-71, fig. 2. – *pratensis* (non De Man, 1880): Thorne, 1934: 755-757 (*Anguillulina*).

Pratylenchus wescolargicus Corbett, 1983. – Corbett, 1983: 396-399, figs 3, 5 (e, f).

Pratylenchus zeae Graham, 1951. – Graham, 1951: 8-11; Sher & Allen, 1953: 452, pl. 65 (a-f) (redescription with the neotype designation); Merny, 1970 (description of male). – *cubensis* Razhivin & Oreli, 1976: 135-136, fig.

Species et subspecies inquirendae

Pratylenchus bicaudatus (Meyl, 1951) Meyl, 1953
Pratylenchus brevicercus Das, 1960
Pratylenchus cerealis Haque, 1966
Pratylenchus chrysanthus Edward, Misra, Rai & Peter, 1969
Pratylenchus coffeae brasiliensis Lordello, 1956
Pratylenchus globulicola Romanico, 1960: 1256-1257, fig. (possibly a valid species with *P. pseudopratensis* Seinhorst, 1968 as its junior synonym)
Pratylenchus heterocercus (Kreis, 1930) Andrássy, 1960
Pratylenchus indicus Das, 1960
Pratylenchus kolourus Fortuner, 1985 (= *Tylenchus* (*Chitinotylenchus*) *coffeae brevicauda* Rahm, 1928)
Pratylenchus montanus Zyubin, 1966
Pratylenchus obtusicaudatus Romanico, 1977
Pratylenchus obtusus (Bastian, 1865) Goodey, 1951
Pratylenchus pratensis bicaudatus Meyl, 1954
Pratylenchus pratensis tenuistriatus Meyl, 1953
Pratylenchus sacchari (Soltwedel, 1888) Filipjev, 1936
Pratylenchus stupidus Romanico, 1977
Pratylenchus tenuis Thorne & Malek, 1968
Pratylenchus tulaganovi Samibaeva, 1966
Pratylenchus tumidiceps Merzheevskaya, 1951
Pratylenchus uralensis Romanico, 1966
Pratylenchus variacaudatus Romanico, 1977

Nomina nuda

Pratylenchus angelicae Kapoor, 1983
Pratylenchus himalayaensis Kapoor, 1983
Pratylenchus menthae Kapoor, 1983
Pratylenchus peerlari Chawla & Prasad, 1973 (= *P. ranjani* Khan & Singh, 1975)
Pratylenchus rhizasinus Sher, 1948

Species transferred to other families

Pratylenchus dendrophilus (Marcinowski, 1909) Filipjev, 1936, now *Neoditylenchus dendrophilus* (Anguinidae)

Pratylenchus graminophilus (Goodey, 1933) Filipjev, 1936, now *Anguina graminophila* (Anguinidae)

Pratylenchus tumifaciens (Cobb, 1932) Filipjev, 1936, now *Anguina tumifaciens* (Anguinidae)

Characters of the genus *Pratylenchus*
(Characters and character states used in the multientry key to the genus)

Character 1. Tail tip shape.
1, pointed;
2, conically rounded;
3, rounded;
4, spherical;
5, truncate;
6, bilobed;
7, irregular;
8, conical with heel-like dorsal outline;
9, obliquely truncate.

Character 2. Tail tip annulation.
1, smooth;
2, smooth with 1-2 incisures on terminus surface;
3, smooth with 1 or 2 annuli;
4, regularly annulated (terminal annuli of equal width);
5, irregularly annulated (terminal annuli of markedly different width).

Character 3. Head annuli.
1, absent;
2, two annuli;
3, three annuli;
4, four annuli;
5, five annuli;
6, six or more annuli.

Character 4. Stylet length.
1, 12 μm or less;
2, 13 μm;
3, 14-15 μm;
4, 16-17 μm;
5, 18-19 μm;
6, 20-22 μm;
7, 23 μm or more.

Character 5. Ratio of tail length to anal body width (*c'*).
1, 1.9 or less;
2, 2.0-2.4;

3, 2.5-2.9;
4, 3.0-3.4;
5, 3.5-4.0;
6, 4.1 or more.

Character 6. Number of tail annuli.
1, 12 or smaller;
2, 13-15;
3, 16-19;
4, 20-25;
5, 26-31;
6, 32 or more.

Character 7. Cephalic region.
1, offset, separated from the body by marked constriction;
2, continuous, not separated from the body by marked constriction.

Character 8. Index *V* (ratio: length of prevulval body part to body length).
1, 67 or less;
2, 68-70;
3, 71-73;
4, 74-76;
5, 77-79;
6, 80-82;
7, 83-84;
8, 85 or more.

Character 9. Index *c* (ratio of body length to tail length).
1, 16 or less;
2, 17-18;
3, 19-22;
4, 23-25;
5, 26-28;
6, 29 or more.

Character 10. Body length.
1, 310 µm or less;
2, 320-350 µm;
3, 360-400 µm;
4, 410-450 µm;
5, 460-500 µm;
6, 510-550 µm;
7, 560-600 µm;
8, 610 µm or more.

Character 11. Index *a* (ratio of body length to maximum body width).
1, 17 or less;
2, 18-21;
3, 22-24;
4, 25-26;
5, 27-28;
6, 29-31;
7, 32 or more.

Character 12. Index *b* (ratio of body length to oesophagus length till oesophago-intestinal valve).
1, 4.6 or less;
2, 4.7-5.5;
3, 5.6-5.8;
4, 5.9-6.5;
5, 6.6-7.0;
6, 7.1-7.5;
7, 7.6-8.2;
8, 8.3-8.5;
9, 8.6 and more.

Character 13. Cephalic framework sclerotization.
1, light;
2, moderate;
3, hard.

Character 14. Stylet knobs.
1, directed anteriorly;
2, directed laterally;
3, directed posteriorly.

Character 15. Lateral field incisures at mid-body.
1, four;
2, five;
3, six.

Character 16. Lateral field areolation.
1, absent;
2, present at mid-body;
3, present in tail.

Character 17. Lateral field incisures between phasmid and tail tip.
1, one;
2, two;
3, three;
4, four.

Character 18. Sperm in female spermatheca.
1, nuclear, nucleus occupying whole sperm diameter of 1 µm;
2, nuclear, nucleus occupying whole sperm diameter of 3 µm;
3, cytoplasmic, nucleus occupying 1/2 of sperm diameter, which is 5 µm;
4, absent.

Character 19. Tail shape.
1, conical;
2, subcylindrical;
3, cylindrical.

Character 20. Median bulb.
1, round;
2, oval.

Character 21. Female spermatheca structure.
1, filled with sperm, round;
2, filled with sperm, oval;
3, without sperm, distinct, offset, with round or oval cavity;
4, without sperm, distinct, offset, with slit-like cavity;
5, indistinct, not offset from outline of female genital tract.

Character 22. Spicula length.
1, 14 µm or less;
2, 15 µm;
3, 16 µm;
4, 17 µm;
5, 18 µm;
6, 19 µm;
7, 20 µm;
8, 21 µm or more;
9, males absent, spermatheca of females without sperm.

Character 23. Posterior genital branch differentiation.
1, 1-3 oocytes;
2, 4-5 oocytes;
3, 6 and more oocytes;
4, 2-5 somatic nuclei in compact body;
5, 6 and more somatic nuclei in compact body;
6, absent.

Character 24. Posterior genital branch length.
1, one vulval diameter (18-20 µm) or less;
2, 1.1-1.3 vulval diameters (21-25 µm);
3, 1.4-1.6 vulval diameters (26-30 µm);
4, 1.7-1.9 vulval diameters (31-36 µm);
5, 2.0-2.3 vulval diameters (37-44 µm);
6, 2.4 vulval diameters (45 µm) or more.

Character 25. Gland lobe length.
1, 39 µm or less;
2, 40-46 µm;

3, 47-50 µm;
4, 51-55 µm;
5, 56-60 µm;
6, 61-65 µm;
7, 66-70 µm;
8, 71 µm or more.

Character 26. Central band of lateral field.
1, narrower than lateral ones;
2, wider than lateral ones;
3, equal in width to lateral ones.

Multientry polytomous key to the genus *Pratylenchus* (Table)

Numbers of characters (columns of Table) correspond to those in the list of characters given above. In each cell, the numbers of the character states (from 1 to 9) are given, which are known for the species in the corresponding line of the Table. If the species has several states of the same character, they are given as a row of digits (from 1 to 9) without blank spaces.

Synonymy

Pratylenchus scribneri Steiner in Sherbakoff & Stanley, 1943 = *P. jordanensis* Hashim, 1983, **syn. n.**

P. jordanensis is identical to *Pratylenchus scribneri* in the main 26 diagnostic characters (see Table). There are no differences in the body length (410-620 µm in *P. scribneri* vs. 380-590 µm in *P. jordanensis*), stylet length (14-18 µm vs.14-15 mm), number of lip annuli (2), values of indices *V* (73-82 vs.75-79) and *c* (13-21 vs.16-25), in cylindrical rounded shape of tail, smooth tail terminus, and number of annuli on the ventral side of the tail (18-30 vs. 19-24). Unique diagnostic character of *P. scribneri* is the second lip annulus, which is significantly wider than the first lip annulus. This feature is typical of *P. jordanensis* as well. Conclusion on the synonymy is based on these similarities. The synonymy has been confirmed also by the analysis made by BIKEY system (the module "Check taxa differences").

Computerized multientry image-operating diagnostic system of the genus *Pratylenchus*

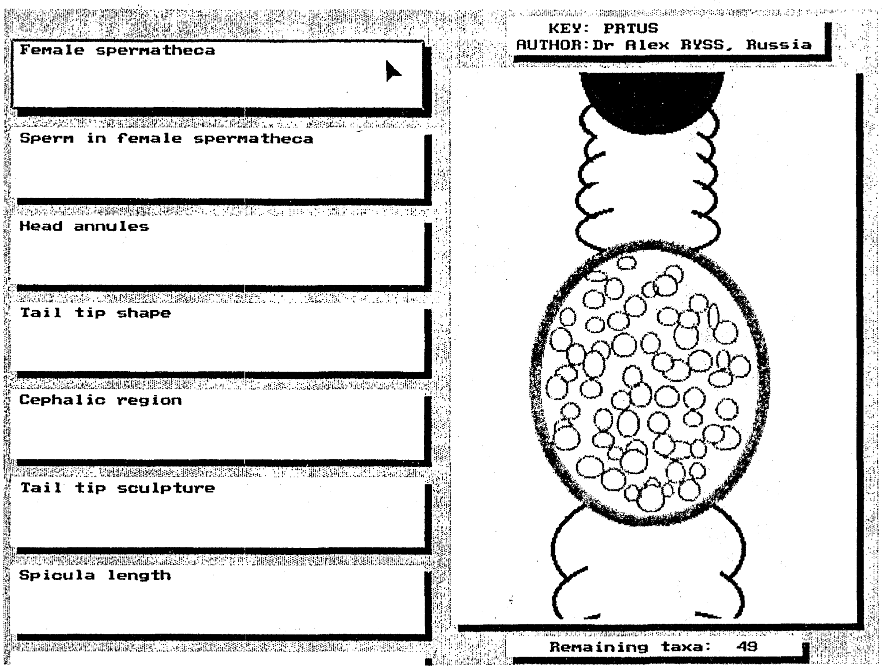
By conversion of the above-described multientry key into a file of the DBF format and the subsequent export of this file into the diagnostic system BIKEY-PICKEY (Lobanov & Dianov, 1994; 1995, Lobanov et al., 1996; Dianov & Lobanov, 1997), the computerized key of the genus has been developed. The computerized keys created in the system of Lobanov and Dianov have several advantages in comparison with monoentry keys. These advantages were analysed by Lobanov & Ryss (1999). The basic principle of identification of species in multientry computerized key is the filtration of the database of species characters by the character state of the specimen to be identified. User can apply any character of the key at each step of identification. In addition, BICKEY has the built-in algorithm that proposes the sequence of characters depending on their comparative ability to reach an identification by the minimum number of steps. At each step, the characters are ranged depending on their diagnostic values calculated by the algorithm. Sequence of characters is recalculated at each step of identification. Algorithm ranges the characters depending on their ability to divide (by the character states) the given species set into the maximum number of groups consisting of approximately the same number of species. Thus, the algorithm reduces the *average* number of identification steps. The character which is the best according to the criterion is situated at the first place at each identification step. Algorithm has been developed by the Australian computer biologist Dallwitz (Dallwitz, 1974; Dallwitz & Paine, 1986). The diagnostic system does not impose the choice of the character on user and only gives him recommendations.

Algorithm of Dallwitz lines up the characters depending on their diagnostic values. At the first step of identification (i.e., for all the species of the genus *Pratylenchus*), the sequence of characters is as follows:

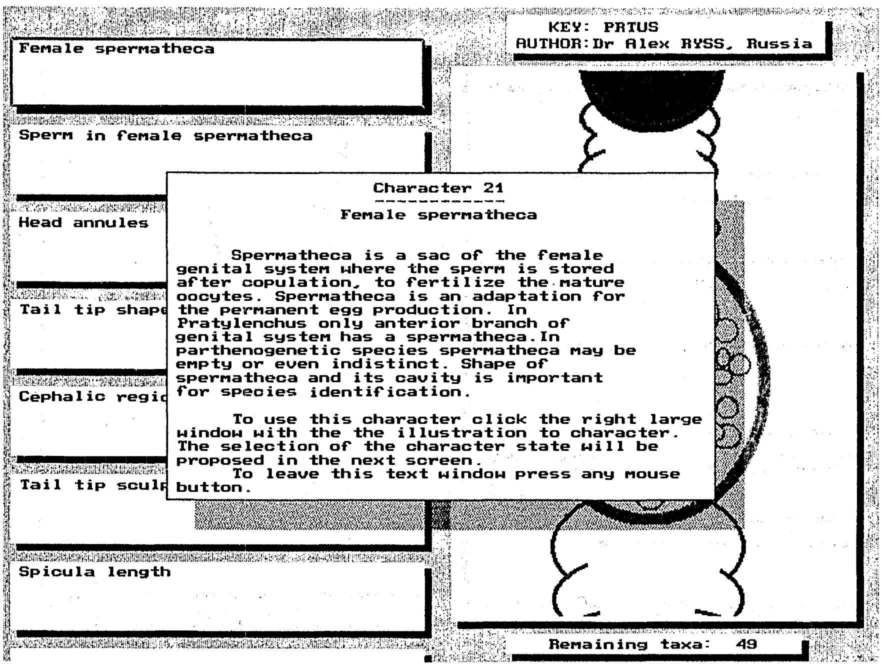
1) female spermatheca (21);
2) sperm in female spermatheca (18);
3) number of head annuli (3);
4) tail tip shape (1);
5) cephalic region (7);
6) tail tip sculpture (annulation) (2);
7) spicule length (22);
8) number of incisures of the lateral field between phasmid and tail tip (17);
9) gland lobe length (25);
10) differentiation of the posterior genital branch (23);
11) median bulb (20);
12) cephalic framework sclerotozation (13);
13) lateral field areolation (16);
14) tail shape (19);
15) central band of lateral field (26);
16) stylet knobs (14);
17) lateral field incisures at mid-body (2);
18) number of tail annuli (6);
19) stylet length (4);

Table. Structure of the database of characters (DBF format), which is at the same time the multientry key to species of the genus *Pratylenchus* Filipjev. Characters are listed in the text

LATNAM	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26
alleni	3	13	2	3	12	3	1	567	1234	234	2345	234	1	2	1	1	23	1	2	1	12	123	126	234	1	3
andinus	34	1	3	341	12	3	1	56	23	567	34567	34567	2	2	1	3	4	4	3	2	3	9	6	1234	1234	3
australis	2	1	3	56	123	4	2	567	23	78	4567	4567	3	2	1	1	3	4	1	2	5	9	6	234	45	3
barkati	5	4	3	5	3	3	1	45	23	56	456	89	2	2	1	1	4	4	2	1	3	9	6	1	7	3
bolivianus	123	1	34	456	12	234	1	6	123	678	456	1234	3	2	1	2	4	4	12	2	3	9	6	234	123	2
brachyurus	35	1	2	56	12	234	1	78	1234	45678	23456	23457	3	2	1	1	2	4	2	1	5	9	6	123	4	3
coffeae	3	145	2	345	34	4	1	567	1234	45678	23456	23457	2	2	1	1	34	1	12	12	2	345	16	12345	1	3
convallariae	367	5	3	34	12	34	1	56	2345	567	345	45678	2	2	1	1	3	1	2	1	1	23	56	34	1	3
crassi	3	1	2	45	2	12	1	345	234	4	234	789	2	2	1	1	4	1	2	1	2	12345	6	1	1	3
crenatus	3	4	3	345	23	45	1	567	12345	34567	23456	23457	2	3	3	1	4	4	2	1	3	9	6	3	1	3
dasi	35	1	3	5	4	2	1	345	123	4567	3456	789	2	2	1	1	4	4	2	1	3	9	6	23	3	3
delattrei	2	1	3	3	2	123	1	3456	23	345	234	12	2	2	1	1	4	4	12	1	5	9	6	2	1	3
ekrami	2	1	3	12	123	56	2	567	23456	45678	34567	23456	2	3	1	1	4	1	1	12	2	2	1	45	1234	3
emarginatus	3	1	3	34	123	34	1	3	12	1	1	12	2	2	1	1	34	1	2	1	12	12	6	1	1	3
estoniensis	3	4	2	4	12	45	1	678	123	2345	12345	12346	2	1	3	1	4	4	2	2	3	9	6	23	1	3
exilis	3	4	3	45	3	34	1	34	123	567	67	9	2	2	1	1	4	1	2	1	1	3	6	1	4	3
fallax	3	4	3	4	23	34	1	56	234	4567	34567	2345	2	2	1	1	4	1	2	1	1	123	16	23	3	3
flakkensis	4	4	2	4	23	34	1	345	12	4567	2345	2345	2	2	1	1	4	1	23	1	1	2	16	3	1	3
gibbicaudatus	356	4	2	34	12345	456	1	34	123	456	23456	23456	2	2	1	1	23	4	2	1	3	5	56	12345	23456	3
goodeyi	8	1	4	34	3	34	1	34	12	45678	4567	234	2	2	1	1	234	3	1	1	12	23	6	123	1	3
hexincisus	3	1	2	34	1	4	1	456	234	23456	23456	45678	2	2	3	1	4	4	2	1	5	34	6	1	1	3
impar	23	4	2	34	34	456	1	123	1234	45	34	12	2	2	1	1	4	4	2	12	5	9	16	3	1	2
japonicus	12	1	2	56	12346	45	2	78	123	45678	12347	34567	2	2	1	13	3	4	1	1	3	9	6	1234	6	3
jordanensis	23	12	2	3	234	34	1	45	1234	34567	4567	1234	2	2	1	1	3	4	12	12	3	9	6	1	1234	3
kasari	1	45	3	45	45	6	2	456	123	45678	7	34567	2	2	12	1	4	2	1	2	2	5678	5	5	8	3
loosi	2	1	2	345	34	345	1	5678	234	5678	567	3456	2	2	123	1	3	1	1	1	12	34567	16	12	12	3
macrostylus	2	13	2	67	234	34	2	8	1234	678	3	23456	2	2	12	1	3	4	1	12	35	29	1	23	34	3
microstylus	13	1	3	1	2	34	2	45	123	2345	234	234	2	2	1	1	4	4	12	12	5	9	6	1	12	3
mulchandi	35	1	3	345	1	23	1	56	23	456	1234	234	2	1	1	1	4	4	2	1	5	9	3	3	2	3
neglectus	259	1	2	345	12	23	1	567	123	45678	23456	23456	2	12	13	1	24	4	23	1	4	9	6	1	1	3
nizamabadensis	4	4	4	5	12	2	2	2345	2345	456	345	56789	3	2	1	1	4	4	2	1	5	9	6	12	1	3
penetrans	2	1	3	34	12	2345	1	4567	1234	45678	23456	23456	2	2	1	123	4	1	12	1	1	1234	46	123	1	3
pinguicaudatus	4	1	3	45	23	4	1	56	123	678	2345	345	2	2	1	123	3	4	23	1	3	9	46	12	4567	3
pratensis	12	4	3	23	23	45	1	45	23	4567	34567	234	2	2	1	1	24	1	12	2	2	456	6	123	2	3
pseudocoffeae	2345	1	23	345	123	34	1	567	23	45678	34567	12345	2	12	1	3	34		123	2	2	23456	12	12345	678	3
pseudopratensis	345	1	34	23	12	123	1	456	34	3456	23456	3456	2	2	12	1	4	1	2	1	2	1234	6	1	1	3
ranjani	45	1	4	34	1	456	2	456	123	5678	4567	12	2	2	1	1	4	4	23	1	5	9	6	45	23	2
scribneri	37	1	2	34	23	45	1	456	123	45678	23456	34567	2	2	12	1	34	4	23	12	3	9	6	123	1	3
sefaensis	35	12	3	34	123	34	1	56	234	3456	456	2345	2	2	1	1	3	4	2	2	3	123	14	1234	12	23
sensillatus	456	1	3	34	123	234	1	56	3456	78	567	678	2	2	1	2	34	4	23	2	5	9	5	1234	12345	23
similis	3	4	2	12	3	3	1	45678	1234	345	23456	1	2	2	1	1	4	1	12	12	2	1	6	5	1	2
subranjani	23569	145	3	45	345	456	2	56	12	34567	34567	23457	2	12	1	23	24	4	12	2	45	9	6	3456	12345	3
sudanensis	45	1	3	34	1234	34	1	34	1234	34567	3456	23456	2	2	12	1	3	1	2	1	12	45	6	123	1	3
teres	3	4	3	45	12	45	1	2345	12345	34	23	1	2	12	3	1	1	4	2	12	5	9	6	1	5	3
thornei	5	1	3	45	3	345	2	3456	234	5678	4567	34567	2	2	13	1	4	4	3	12	45	8	46	123	1	23
unzenensis	45	15	3	34	2345	456	2	45	1	345	3456	234	2	2	1	23	24	1	12	2	2	1	6	1234	12345	3
vulnus	279	1	34	45	234	45	2	567	12345	5678	567	23456	2	2	1	1	234	1	1	2	2	34567	12	56	45	1
wescolargicus	3	1	34	45	23	3	1	56	234	5678	4567	2345	3	1	1	23	3	4	2	2	3	9	6	1	123	3
zeae	2	1	3	34	4	5	2	234	123	45678	23456	34567	2	2	1	1	4	4	1	12	4	9	6	1234	2345	3

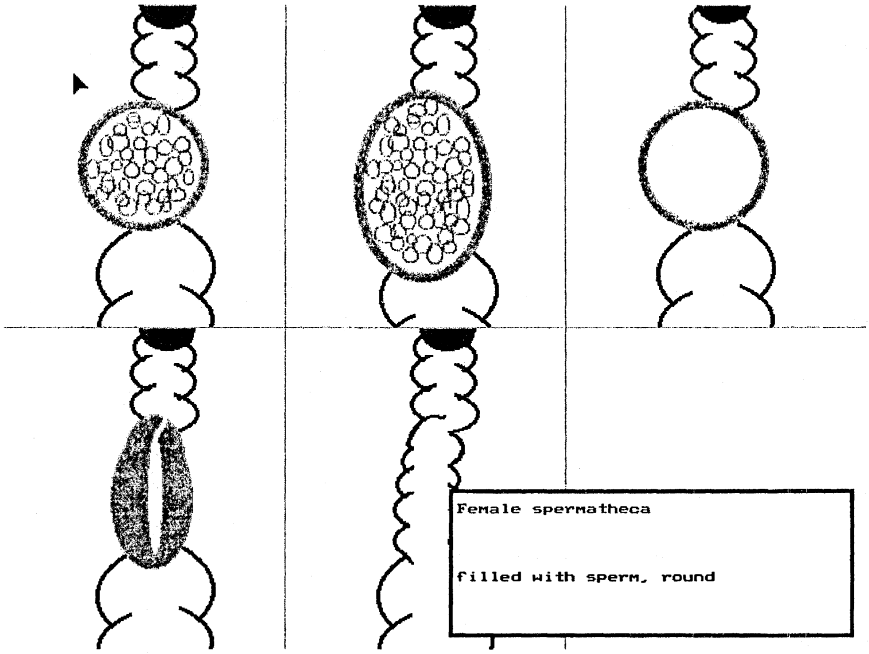


1

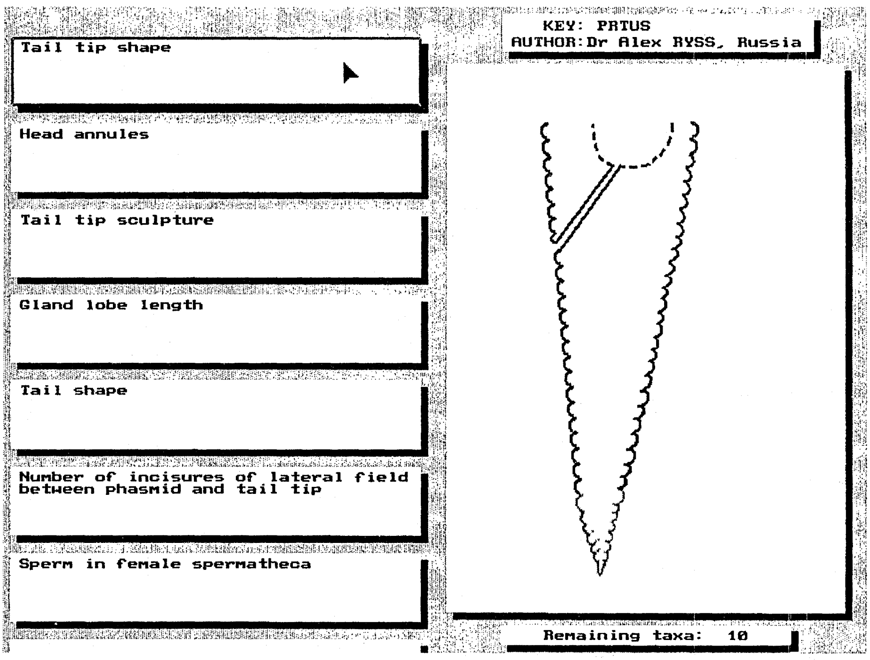


2

Figs 1-2. Identification of species of the genus *Pratylenchus* in the multientry computerized image-operating key developed in the diagnostic system BICKEY-PICKEY. **1**, first screen of the key with the optimized sequence of characters and full set of taxa (49); to the right is the image of character on which name the mouse pointer is situated. **2**, user can click the name of the character to see its detailed description and comments.

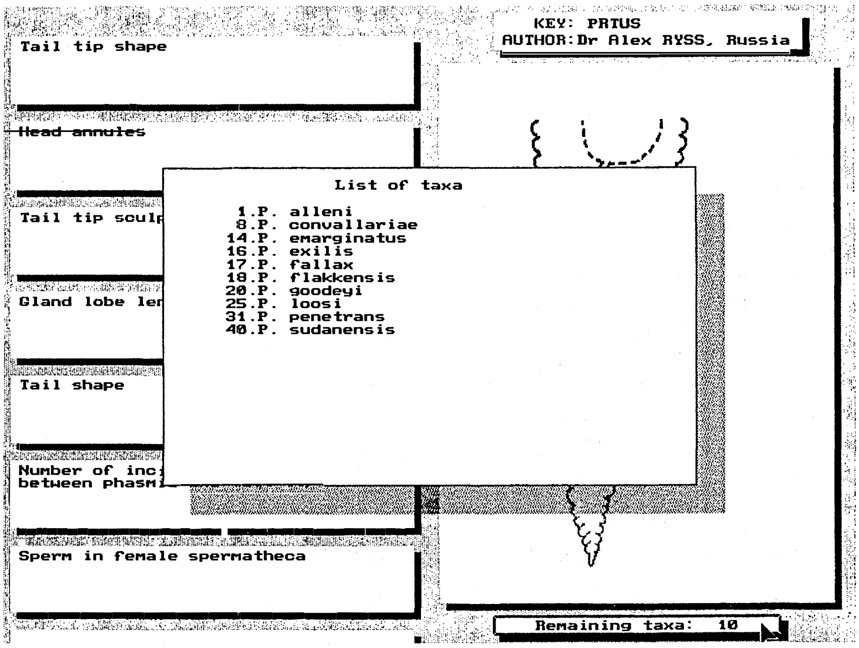


3

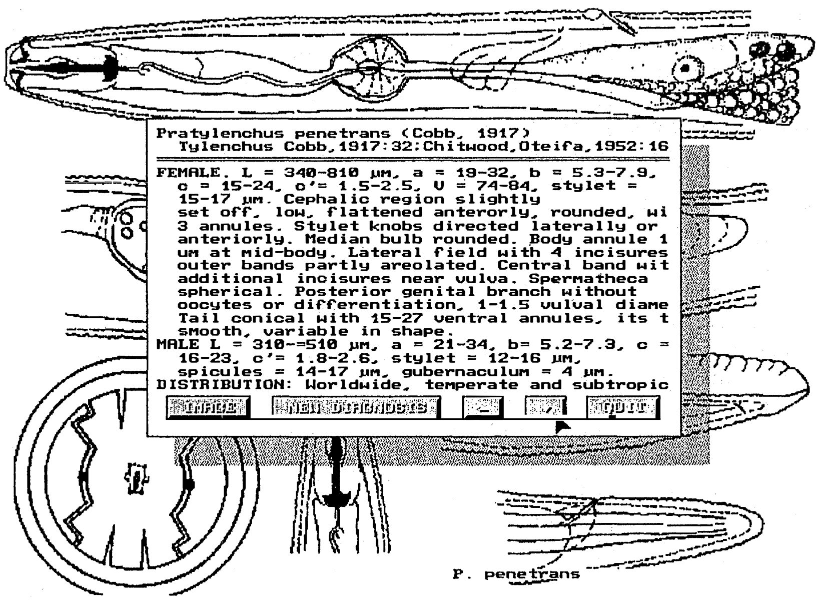


4

Figs 3-4. Identification of species of the genus *Pratylenchus* in the multientry computerized image-operating key developed in the diagnostic system BICKEY-PICKEY. **3,** clicking (selection) of the image of character leads to appearance of the second screen with the set of character states and a frame of comments to the state near the mouse pointer; the frame changes its position and text with the mouse pointer travel. **4,** after clicking (choice) of the character state, the system filters the database of species and the first screen appears again with the reduced number of species (10; see to the right at the bottom) and the new optimized sequence of characters differing from that in Fig 1.



5



6

Figs 5-6. Identification of species of the genus *Pratylenchus* in the multientry computerized image-operating key developed in the diagnostic system BICKEY-PICKEY. **5,** user can click the frame with a number of species in the current species set (below to the right) to see the list of these species names. **6,** final of the species identification: the species image and name appear, after clicking the "DESCRIPTION" screen button the scrolling text of the species morphological description appears with the list of the species synonymy, its geographical distribution, hosts, soil types, biotopes and bibliography.

20) ratio of tail length to anal body width (c') (5);
21) length of the posterior genital branch (24);
22) index V (8);
23) index c (9);
24) index a (11);
25) index b (12);
26) body length (10).

The index of key perfection for the computerized diagnostic system of *Pratylenchus* is 9.3, whereas the maximum value is 10.

Here below the identification by the key developed in the BICKEY-PICKEY system is illustrated on the example of *Pratylenchus penetrans*. At the first step, the user selects the character taking into account the sequence of characters proposed by the algorithm. In Fig. 1, the character "shape of spermatheca" is selected. By clicking the mouse, user opens the second screen of the system for selection of the character state corresponding to that in the specimen under identification. In Fig. 2, the state "spermatheca round, with sperm" is selected. User clicks the chosen state image making his selection, and the set of species is being filtered by the character state. In the right lower corner of Fig. 1, it can be seen that the initial set of species is 49, whereas after the filtration (Fig. 3) the number of species is reduced to 10 (Fig. 4). Simultaneously, the sequence of proposed characters is automatically changed (compare Figs 1 and 4). This filtered set (species names) can be easily seen by clicking the frame with the species number (compare Figs 4 and 5). It is possible to see the detailed morphological and biological comments to each character by clicking the frame with the name of character (Fig. 2). Passing several steps of identification, user reaches the final identification (Fig. 6): the final screen with the species name, its illustration and scrolling description, which includes synonymy, diagnosis, data on distribution, list of host plants, brief data on the life history and ecology, soil types of habitats, and the main bibliography. The nematode key operation and its features are described in detail on examples of the genus *Radopholus* and family Pratylenchidae (Ryss et al., 1995, 1996; Ryss, 1997a, 1998b).

Monoentry polytomous key to species of the genus *Pratylenchus* (mainly to females)

1. *Female spermatheca*
   - filled with sperm, oval 2
   - filled with sperm, round 6
   - without sperm, distinct, offset, with round or oval cavity 9
   - without sperm, distinct, offset, with slit-like cavity 38
   - indistinct, not offset from outline of female genital tract 13
2. *Tail tip shape*
   - conical with heel-like dorsal outline ...... **P. goodeyi**
   - irregular or obliquely truncate .... **P. vulnus**
   - pointed 33
   - conically rounded 23
   - rounded 3
   - spherical or truncate 40
3. *Head annuli*
   - four .... **P. pseudopratensis**
   - two 4
   - three 25
4. *Number of tail annuli*
   - 15 or less .... **P. crassi**
   - 16-19 5
   - 20-25 19
5. *Cephalic framework sclerotization*
   - light .... **P. alleni**
   - moderate 42
6. *Tail tip shape*
   - truncate .... **P. sudanensis**
   - conical with heel-like dorsal outline ...... **P. goodeyi**
   - irregular or bilobed .... **P. convallariae**
   - conically rounded 36
   - rounded 7
   - spherical 31
7. *Tail tip sculpture*
   - smooth with 1 or 2 annuli .... **P. alleni**
   - smooth, without annuli or incisures 8
   - irregularly annulated (terminal annuli of markedly different width) .... **P. convallariae**
   - regularly annulated (terminal annuli of equal width) 30
8. *Head annuli*
   - two .... **P. alleni**
   - three .... **P. emarginatus**
9. *Head annuli*
   - three 10
   - four 17
   - two 27
10. *Median bulb*
    - oval 11
    - round 16
11. *Cephalic framework sclerotization*
    - moderate 12
    - hard 17
12. *Lateral field areolation*
    - present on tail .... **P. andinus**
    - absent .... **P. sefaensis**
13. *Head annuli*
    - three 14
    - two 18
    - four 39
14. *Cephalic region*
    - continuous, not separated by marked constriction from body 15
    - offset, separated by marked constriction from body 21
15. *Cephalic framework sclerotization*
    - hard .... **P. australis**
    - moderate 43
16. *Number of tail annuli*
    - 13-15 .... **P. dasi**
    - 16-19 .... **P. barkati**

– 20-25 20
– 26-31 .... **P. scribneri**

17. *Stylet knobs*
– directed anteriorly .... **P. wescolargicus**
– directed laterally .... **P. bolivianus**

18. *Number of incisures of lateral field between phasmid and tail tip*
– two .... **P. brachyurus**
– three .... **P. macrostylus**
– four 32

19. *Lateral field areolation*
– present on tail .... **P. pseudocoffeae**
– absent .... **P. coffeae**

20. *Tail tip shape*
– rounded .... **P. crenatus**
– spherical .... **P. pinguicaudatus**
– irregular .... **P. scribneri**

21. *Posterior genital branch differentiation*
– 6 and more oocytes .... **P. mulchandi**
– 6 and more somatic nuclei in compact body .... **P. sensillatus**
– oocytes or nuclei absent 22

22. *Tail tip shape*
– conically rounded .... **P. delattrei**
– rounded .... **P. teres**

23. *Cephalic region*
– continuous, not separated by marked constriction from body 24
– offset, separated by marked constriction from body 34

24. *Stylet knobs*
– directed laterally .... **P. vulnus**
– directed posteriorly .... **P. ekrami**

25. *Lateral field areolation*
– absent 26
– present on tail .... **P. pseudocoffeae**

26. *Index V*
– 73 or less .... **P. emarginatus**
– 74 or more .... **P. pseudopratensis**

27. *Cephalic region*
– offset, separated by marked constriction from body 28
– continuous, not separated by marked constriction from body 37

28. *Tail tip sculpture*
– smooth, without annuli or incisures 33
– regularly annulated (terminal annuli of equal width) 29

29. *Stylet knobs*
– directed anteriorly .... **P. estoniensis**
– directed laterally .... **P. gibbicaudatus**

30. *Gland lobe*
– 50 mm or shorter .... **P. fallax**
– 51 mm or longer .... **P. exilis**

31. *Tail tip sculpture*
– smooth, without annuli or incisures .... **P. sudanensis**
– regularly annulated (terminal annuli of equal width). .... **P. flakkensis**

32. *Tail tip sculpture*
– smooth, without annuli or incisures .... **P. hexincisus**
– regularly annulated (terminal annuli of equal width) .... **P. impar**

33. *Cephalic region*
– offset, separated by marked constriction from body .... **P. pratensis**
– continuous, not separated by marked constriction from body .... **P. kasari**

34. *Tail tip sculpture*
– regularly annulated (terminal annuli of equal width) .... **P. pratensis**
– smooth, without annuli or incisures 35

35. *Lateral field areolation*
– present on tail .... **P. pseudocoffeae**
– absent .... **P. loosi**

36. *Head annuli*
– two .... **P. loosi**
– three .... **P. penetrans**

37. *Posterior genital branch differentiation*
– 1-3 oocytes .... **P. macrostylus**
– oocytes or nuclei absent .... **P. japonicus**

38. *Head annuli*
– two .... **P. neglectus**
– three 43

39. *Tail tip sculpture*
– smooth, without annuli or incisures .... **P. ranjani**
– regularly annulated (terminal annuli of equal width) .... **P. nizamabadensis**

40. *Median bulb*
– round 41
– oval 46

41. *Number of incisures of lateral field between phasmid and tail tip*
– three .... **P. sudanensis**
– four .... **P. pseudopratensis**

42. *Tail tip sculpture*
– smooth, without annuli or incisures .... **P. pseudocoffeae**
– regularly annulated (terminal annuli of equal width) .... **P. similis**

43. *Stylet length*
– 12 µm or less .... **P. microstylus**
– 14 µm or more 44

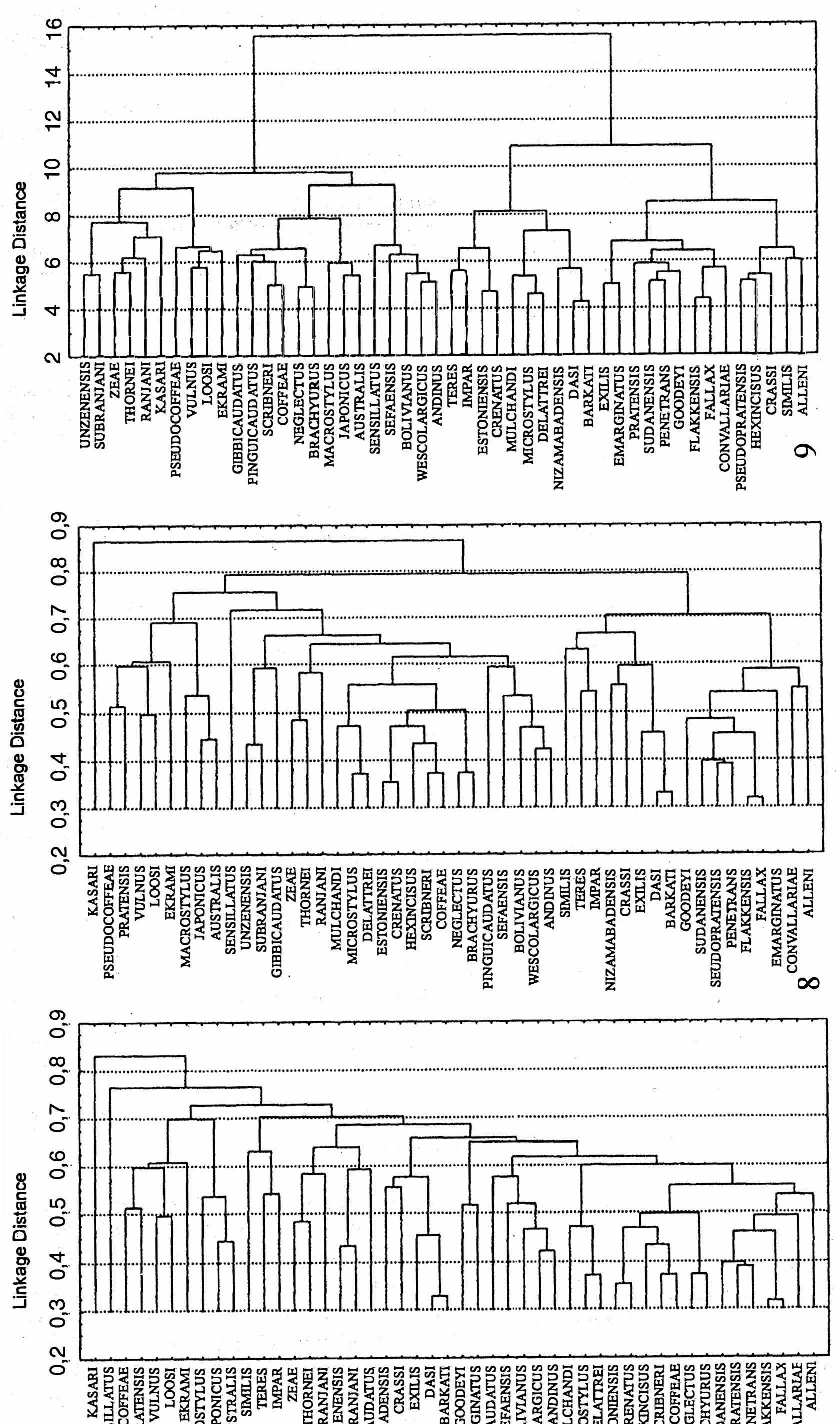
44. Tail tip annulated, lateral field areolated at mid-body and tail .... **P. subranjani**
– Tail tip smooth, lateral field not areolated 45

45. Tail tip truncate, *c′* (ratio of tail length to anal body width) less than 3, index *V* more than 76 ... **P. thornei**
– Tail tip narrow, conically rounded, index c' more than 3, index *V* less than 76 .... **P. zeae**

46. *Cephalic region*
– offset, separated by marked constriction from body .... **P. pseudocoffeae**
– continuous, not separated by marked constriction from body .... **P. unzenensis**

Phenetic dendrogram of species of the genus *Pratylenchus*

To detect the groups of *Pratylenchus* species and their relative similarity in diagnostic characters, the cluster analysis (joining or tree clustering method) was used. The following amalgamation (linkage) rules were applied: UPGMA (Unweighted Pair-Group Average), WPGMA (Weighted Pair-Group Average) and Ward's method (estimation of the similarity by the data profile). The following distance measures were used: 1-Pearson r index and Euclidean distance. Initial data were taken from the Table of species characters, which was pre-transformed in the following way: because the states of each char-



Figs 7-9. Dendrograms of the cluster tree analysis of the morphological similarity of the genus *Pratylenchus* prepared in the STATISTICA package. **7:** UPGMA linkage with Pearson r as the distance measure; **8:** WPGMA linkage with Pearson r as the distance measure; **9:** Ward's method linkage with Euclidean distances.

acter form an unidirectional row, the averages for each of 26 characters in each species were calculated. The average values were used for the tree cluster analysis. The most indicative and corresponding to the views of taxonomists on the species groups is the dendrogram obtained by the UPGMA method with the distance measure of 1-Pearson r (Figs 7-9).

Notes on the evolution of the genus *Pratylenchus*

Surely the phenetic dendrogram does not reflect the evolution of the genus, but only shows the grade of the phenetic similarity of species in diagnostic characters. The evolution and phylogeny of *Pratylenchus* will be analysed in the next publication. But the sequence of diagnostic characters lined up by the BIKEY algorithm at the first identification step gives an opportunity to make some conclusions. Algorithm uses the alternative states of a character as the tool to split the species set. As stated above, the algorithm selects the characters by their ability to divide the set of species into the maximum number of subsets each relatively equal in the number of species. According to this criterion, the best character (situated in the first position in the sequence of characters at the first identification step) is the structure of spermatheca. This character (Fig. 3) represents a sequence of states of reduction of the spermatheca. Spermatheca is a saclike structure of the female genital system, which preserves sperm after the rare copulations and thus maintains the permanent egg-laying. The morphological row of the spermatheca reduction corresponds to the transition of the species to the parthenogenesis, which is typical of more than 60% species of the genus *Pratylenchus*. The first position of this character in the sequence of characters means approximately equal frequency of each state of the spermatheca reduction in *Pratylenchus* species. Thus, it can be concluded that the transition to the parthenogenesis is one of the leading factors of evolution of species in the genus *Pratylenchus*.

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Received 10 January 2001